Investigation of slider surfaces after wear using Photoemission Electron Microscopy

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INTRODUCTION

The trend of increasing storage density of magnetic storage media at the high rate of 60% annually places very high demands on the materials systems used in these devices. The head/disk interface is one of the key focal points for increasing the storage density further, and this requires improved slider performance, increasingly reduced head disk spacing, and increasingly thinner protective disk overcoats and lubricant thicknesses.

We have applied Photoemission Electron Microscopy (PEEM) to study the elemental and chemical structure and modification of slider surfaces after wear.

PEEM STUDIES OF SLIDERS WORN IN A TRIBOCHAMBER USING LUBRICATED DISKS

A tribochamber consisting of a spindle, an actuator, and a quadrupole mass spectrometer in UHV (base pressure < 10^{-6} Pa) was used for the wear tests [1]. Supersmooth-textured 65 mm disks were coated with 5 nm cathodic arc deposited amorphous hard carbon and lubricated with 0.85 nm of perfluoropolyether (ZDOL) lubricant. Uncoated and coated sliders made from Al_2O_3/TiC were used for the test where the coating was a sputter deposited hydrogenated diamond-like carbon (CH_x) of 6 nm thickness. The continuous drag tests were performed at a drag speed of 0.2 m/s, a load of 30 mN, and a sliding time of 600s.

Substantial scratch marks were found at the surfaces of both, the coated and uncoated slider, after the wear. These areas were studied using the PEEM microscope.

The PEEM microscope used for these studies is located at the undulator beamline 8.0, which is equipped with a spherical grating monochromator having three different gratings to cover the energy range from 200-1500 eV with a resolving power of $E/\Delta E$=10,000. A two-lens, electrostatic microscope operating at a nominal voltage of 10 kV was used for these studies. The microscope is equipped with an aperture at the back focal plane of the objective lens to limit the pencil angle of the electron trajectories and thus increase the resolution. The microscope has a spatial resolution of 200 nm, and it is described in detail in [2].

Figure 1 shows a PEEM image of a scratch we found on a coated slider which was obtained in the following way. An image was acquired at an X-ray energy of 280 eV, which is below the carbon K absorption edge. This image showed mainly topological contrast. Another image was acquired at 300 eV which is the energy of the carbon σ resonance at the K absorption edge [3]. This image showed features due to a superposition of topological and chemical contrast of carbon. Figure 1 is a subtraction of these two images showing contrast only due to the presence of carbon. It shows that there is less carbon in the scratch than the surrounding area which was CH_x coated before the wear.

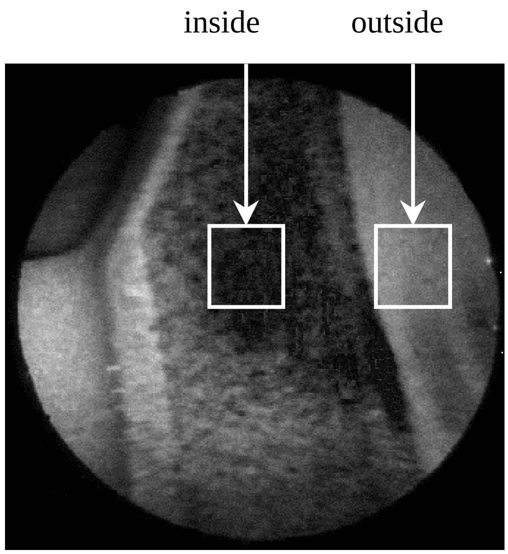

Figure 1: PEEM image of scratch on surface of CH_x coated slider. The boxes mark the areas where local NEXAFS spectra were acquired.

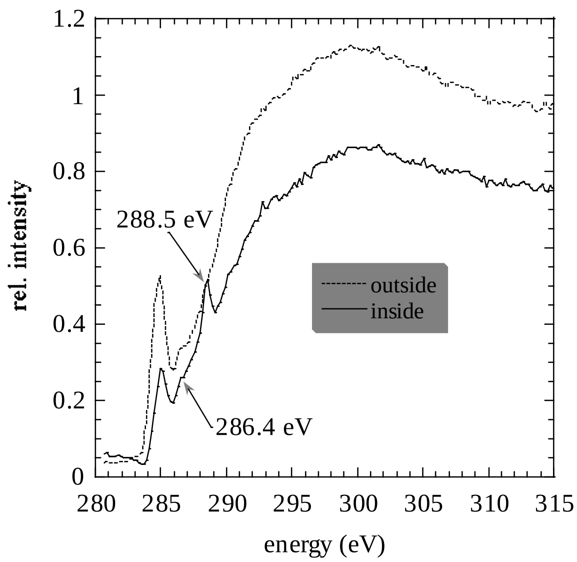

Figure 2: Carbon K edge spectra taken in the areas indicated in Figure 1 of the CH_x coated slider.

Using PEEM we can obtain taking local NEXAFS spectra by selecting small areas of interest on the sample and taking images at incrementally increased X-ray energies. The areas from which local NEXAFS spectra were taken at the surface of the CH_x coated slider are indicated in Figure 1. The carbon K edge spectra shown in Figure 2 are normalized to the incident X-ray flux, and their relative intensity reflects the relative amount of carbon present at the sample surface. The spectrum outside the scratch is a typical diamond-like carbon spectrum with the π^* resonance at 285 eV corresponding to sp^2 bonded carbon atoms, and the broad σ resonance around 300 eV [3-5]. The small peak at 286.4 eV can be attributed to C=O bonds [3, 4], and this small oxygen contamination is probably due to the fact that the slider was exposed to air for a long time after the coating. The striking new feature found in the scratch is the strong peak at 288.5 eV which indicates carboxylic bonds (O=C-OH) [3, 4, 6]. This is remarkable because the spectrum obtained in the scratch is very similar to the spectra taken in wear tracks of hard disks. It was observed that the carbon K edge spectrum in wear tracks of disks lubricated with ZDOL showed the additional carboxylic peak, which was not present in the undisturbed lubricant/hard carbon overcoat of the disks [7, 8]. The spectrum containing the additional carboxylic bond was interpreted as the characteristic feature of degraded lubricant. Unlubricated disks did not show additional peaks or any other variations of the shape of the spectrum of the wear tracks, just a reduction of the total carbon signal [8]. The shape of the carbon spectrum in the scratch indicates that degraded lubricant has been transferred to the slider surface and accumulated in the scratch. It can be seen that a total reduction of the carbon signal was also observed here, the signal is reduced by about 20% in the scratch. Since the carbon signal is a superposition of the CH_x coating on the slider and the lubricant transferred from the disk to the slider, the CH_x thickness is probably reduced considerably.

Figure 3 shows a PEEM image of a scratch on the surface of the uncoated slider. The same procedure was applied as described for Figure 1 (subtracting an image acquired at 280 eV from an image acquired at 300 eV) to obtain contrast only due to the presence of carbon.

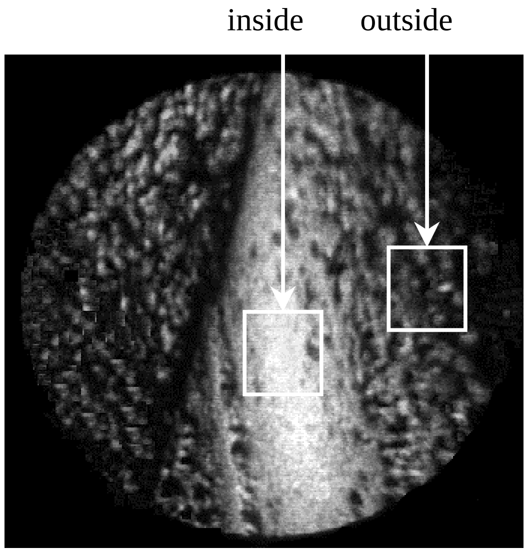

Figure 3: PEEM image of scratch on surface of uncoated slider. The boxes mark the areas where local NEXAFS spectra were acquired.

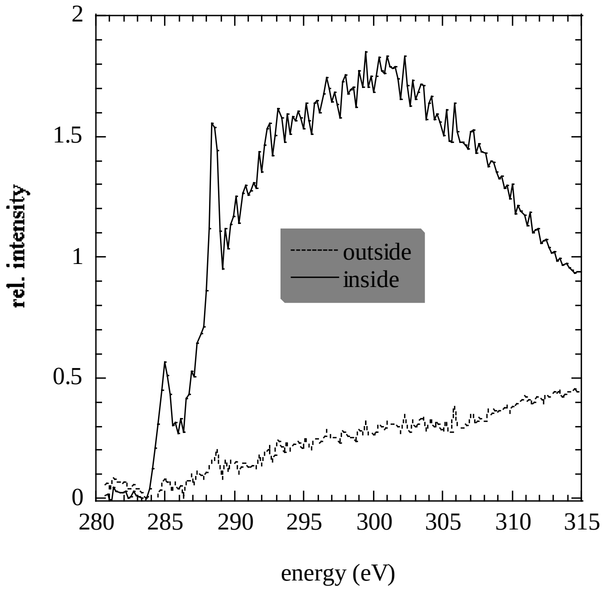

Figure 4: Carbon K edge spectra taken in the areas indicated in Figure 3 of the uncoated slider.

From the carbon K edge spectra (Figure 4) acquired in the areas indicated in Figure 3 and from Figure 3 itself one can see that there is almost no carbon at the surface of the slider except in the scratch. The carbon K edge spectrum in the scratch shows the same signature as the spectrum in the scratch of the CH_x coated slider (Figure 2) and the spectra found in wear tracks of disks lubricated with ZDOL. The carboxylic peak is higher with respect to the π^* and σ resonances because the spectrum is not a superposition of CH_x and degraded lubricant as it was on the coated slider. The oxygen K edge spectra inside and outside the scratch indicated the formation of carboxylic bonds [3, 4, 6] confirming the results from the carbon K edge spectrum. The titanium $L_{2,3}$ edge spectra showed a much stronger titanium signal than the coated slider. The intensity is reduced in the scratch compared to the area outside which shows that material (degraded lubricant) has been deposited at the surface. The reduction is about 60%, therefore the thickness of the deposited degraded lubricant is of the order of the electron escape depth of this material.

DISCUSSION AND CONCLUSIONS

Both carbon coated and uncoated sliders exposed to a wear test in a UHV tribochamber using lubricated disks showed the appearance of scratches at the rail surfaces. It was found that degraded lubricant was transferred from the disk to the sliders and accumulated in the scratches. Local NEXAFS spectra of the degraded lubricant showed the formation of carboxylic bonds, which was also observed in other experiments studying the chemical modification of the lubricant in the wear tracks of disks. It was found that the CH_x slider coating was removed locally during the wear test.

Sliders used in another wear test on unlubricated disks [9] showed no carboxylic bonds in the local NEXAFS spectra. They were also not observed in another experiment in which the wear tracks of unlubricated disks were investigated [8]. Only a reduced thickness of the CH_x coating was found locally on those sliders.

It was found under all conditions studied that tribochemical modifications occur only when a lubricant is present at the disk surface. Without lubricant only a mechanical reduction of carbon coating thickness on the slider surface was found. In the presence of a lubricant the lubricant was altered chemically (oxidized) during the wear and this chemically modified lubricant was transferred to the slider surfaces.

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